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ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT): REFINEMENT OF ENVIRONMENTAL DATA BASE GENERATION SYSTEM

(10) By

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NOTICE

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This technical report has been reviewed and is approved for publication.

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This report documents the current status of the Advanced Simulator for Pilot Training visual data base generation system and the improvements of the software that have been made since delivery of the system.

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TABLE OF CONTENTS PAGE

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REFINEMENT OF ENVIRONMENTAL
DATA BASE GENERATION SYSTEM

I. MODIFICATIONS TO THE ASPT MODELING SYSTEM

This report documents the current status of the Advanced Simulator for Pilot Training (ASPT) Visual Data Base Generation System to reflect the modifications of the software delivered with the original system. The computer time and the manhours required to create and modify visual environments have been reduced substantially. The operator interaction has been simplified by having the computer make default assumptions whenever possible in the normal mode of operation. The messages from the computer have been made clearer, and checks have been added in the software to detect possible erroneous conditions. The Data Base switching has been facilitated by adding redundancy to the error detection and correction and by increasing the available options from which to chose visual environments. Up to 6 completely different visual environments are available for loading in less than 1 minute. Any number of visual environments can be maintained on magnetic tape and loaded in less than 5 minutes.

Direct Access

One of the problems in the off-line modeling was that most of the files were handled sequentially. The environment system has been modified to update on a direct access basis. Three levels of detail are possible for each model, and each level is updated independently. When a model is updated the new level plus any old levels are assembled in a scratch area then moved to the lowest available space big enough to hold the model. A criss-cross directory was added in addition to the existing directory to enable the format of the file itself to remain intact so that all existing programs could still be used.

Operator Communication

It was found that most of the operator messages could be simplified or eliminated by defaulting to the normal condition. Provision was made to accept explicit commands from the operator for runs with special requirements.

Save And Resotre Programs

When the (ASPT) system was delivered, there was only one environment to use and only one version of the software. When environments and special versions of the software were developed as required, the problem of switching systems forced the development of programs for switching systems rapidly and dependably. A moving disk system was added to the fixed disk system required for real-time simulation. The moving disk system has the capability to maintain six environments and six software systems. Switching time between the moving and fixed disks is less than a minute. In addition, any number of systems can be stored on magnetic tape. It turned out that the only way to be sure that data being transferred from one peripheral to another are correct is to include checksums and block numbers. To insure the write was good, it was necessary to read and verify after writing. Since several computer systems were available, it was necessary to transport data from one system to another via magnetic tape. The error rate is much higher on tapes from a different computer system so each record was written three times with a checksum and a block number so that if one of the three was good the tape could be read correctly. This corrected most of the tape problems.

Format Considerations

The environment data base was packed as tightly as feasible so that the space taken up by a model was as small as possible, but drawbacks have become apparent. To unravel the model is difficult and time consuming for both the computer and the programmer. The checkout of any minor change in the software is very difficult since everything in the model following the change is affected. The moving model was handled as a special case with some different size limitations. The procedure for handling the moving model has been changed to make it compatible with the standard models. The addressing of the environment was originally defined to be a sequential string of 4 byte words addressed by relative word number and the reading and writing to be done through one subroutine. This turned out to be a very satisfactory approach.

Selective Viewing

Even though the system provided the ability to fly in the environment with a joystick and observe the scene on the maintenance visual display, there was a need to be able to get to an exact position and orientation anywhere in the environment for alignment, environment inspection, and diagnostic purposes. Software was

generated to allow the operator to position x, y, z, roll, pitch and yaw with simple commands on the teletype or CRT. The operator can move to any desired position and release the joystick to fly.

Listing The Data

When the objects are assembled into models and the models are placed in the environment, the scaling, relocation, and rotation makes the final result quite removed from the original input, so programs were developed to interpret the binary model in the environment and to list the data in a straight forward readable form. The listings are of three types: (1) a one-line summary, (2) a five-line summary, and (3) a complete listing of each level of each model. The summaries are a helpful part of the documentation of the environments.

Modifying Existing Environment

Provision was added to permit limited modification of models after they were already in the environment. The indicators for category, day, night, dusk, visibility and priority can be modified.

II. DESCRIPTION OF MODELING

"The art of defining and storing the visual environment as numerical data in computer memory is called modeling. Once the key visual cues of the real world are identified as a necessary part of the environmental data base (such as a control tower), the modeler then proceeds to define these features in a three-dimensional orthogonal coordinate system.

Items such as maps, photographs, scale drawings, and blueprints serve as source data. Sketches are made approximating each feature with a set of straight line segments or edges. A closed convex set of coplanar edges describes a face to which a gray shade is assigned.

Sets of faces are used to define objects. A two-dimensional object is formed with a set of non-overlapping coplanar faces whereas a three-dimensional object is a set of faces forming a closed convex polyhedron." [1]

"Once the source data is collected and preliminary sketches made, the modeler is then ready to define the features in a form expected by the computer software.

The modeler begins by creating a library of objects to be used in constructing the models and hence the environment. A textured field, a 2-D surface feature, can be constructed with two objects, one overlaying the other." [2]

Objects from the object library area are combined to form two-dimensional (2-D) and three-dimensional (3-D) models and thereby create a model library.

Models from the model library are assembled to form an environment. Each object, model, and environment has its own reference system. Once the coordinates of the vertices of an object have been determined in its reference system the modeler can scale, rotate, and locate an object within the models reference system. In a similar manner models are located and oriented in the environment.

All of the preceding information is collected as numerical data on special coding forms which are used by the keypunch operators in preparing the computer input cards. The information on these cards is then read into the computer by the card reader and validated by the off-line software programs. Error messages are relayed by means of the teletype and lineprinter, and valid data are stored as libraries. The final environment is stored on the two fixed-head discs.

An airfield runway and buildings are typical of models in the environment which are described by a series of data blocks stored on the twin mass storage disc drives. These data blocks are arranged in order of their position on stripes which divide the environment into sections of equal width and length.

The environment is 1250 by 1250 nautical miles. On disc, models are located within two areas, dependent on their diameter. The first area is divided into 6-nautical-mile-wide stripes and contains 3-D models with their diameter less than 400 feet and 2-D models up to 1 mile. The second area divides the environment into 40-nautical-mile stripes and includes 3-D models with a diameter greater than 400 feet and 2-D models larger than 1 mile. Both width stripes cover the entire environment but include different models so that selection algorithms can generate the most realistic scene within system

[1] Eric G. Monroe, Environment Data Base Development Process For The ASUPT
CIG System. AFHRL-TR-75-24, AD-A017845. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, August 1975.

[2] Ibid., P. 7.

constraints on the number of edges. An edge is either the boundary between two shades of gray on a plane or the intersection of two or more planes. Models within stripes are ordered by increasing Y.

The Twin General Purpose SEL 86 computers are given the computed location and aircraft altitude by receiving these data in a common section of memory with a third SEL 86 which is entirely devoted to simulating the aircraft and controlling the motion system.

1. The environment coordinate system is a right hand system with x East, y North, and z up.

2. A face is visible when the vertices (as defined on the face card) appear in clockwise order.

3. The face normals point toward the inside of an object.

4. The moving model and the viewpoint must be rolled 180° about their x-axis to match the rest of the picture.

The test for listability which must be passed by objects within a model and partitions within a complex moving model is that for each three objects, either each separation plane separates more than one pair of objects or there is only one separation plane for each pair of objects. The critical dimension can be used to improve the picture by causing objects to stay in longer or drop out quicker. The overload feature in the on-line software will try to keep the computer from going over the 2560-edge limit by simplifying the picture. The critical dimension and the priority bits allow some control of the overload algorithm. The hood is a fixed model but setting both priority bits will cause the on-line software to move it with the viewpoint.

III. REAL-TIME PICTURE GENERATION

Model Selection

Once the position of the environment is known, the programs within the general purpose computer will select and access from the disc unit the closest set of model environment stripes. These stripes are chosen so that there are as many stripes in front of as there are behind the aircraft position. No matter which way the aircraft turns, subsequent disc accesses need only obtain and delete bounding stripes from the working set.

Internal tables which list potentially visible models are built by the real-time computer programs that specify which models lying on

the stripes should be considered for image generation. Models from both 6 and 40-nautical-mile-wide stripes are selected if they lie within 18 or 100, miles respectively, either side of the aircraft. Selection is made using a binary search routine which examines the ordered list of models within a strip and extracts those which meet the constraints on distance from the current aircraft position.

Each object is described using its own coordinate system. The off-line software converts all the vertex coordinates to corresponding values in a common coordinate system. This common coordinate system is labeled (x, y, z) and has its origin at the intersection of the glideslope with runway 30C at Williams AFB. To do this transformation simply requires knowledge of the distance 'd_i' between (x, y, z) the common coordinate system origin and the origin of each of the coordinate systems used to describe an object. Computation in this step is done once off-line for a new environment or in the update of an old one.

When the current edges approach the 2560 edge capacity, the system declares itself in an overload state. To leave this state, it seeks to reduce the frame capacity first by selecting a lower level of detail for the models in the visual display and second, by reducing the number of models being displayed. If frame edge capacity is reduced satisfactorily, the system starts trying to increase the number of edges. The final product is a list of all potentially visible models specified in the model tables. The resulting list of models are the potentially visible ones in the total visual environment.

Conversion To Edges

To begin the computation of a frame, the coordinates of each edge vertex of all potentialy visible objects (some will obscure others in the final scene) in the (x, y, z) coordinate system are converted to coordinates (u, v, w) which are functions of the viewpoint position. The surfaces that will be visible in the final scene do not include all the surfaces composing each object. For example, the polygon faces will be hidden if located on the rear-facing side of an object or if obscured by objects closer to the viewpoint. For each object surface, a unit-normal vector is predefined in the data base environment. Solving the simpler problem, that of eliminating rear-facing sides of an object, can be done by computing the dot product between the viewpoint-to-vertex and unit normal vectors. If the cosine indicates the resulting angle is acute (90^o), the face is not a visible face. Any edge common to adjacent faces is hidden, if both faces are hidden. Thus, quick elimination of hidden edges reduces the computation load on the visual system.

The next step is conversion to Scan Line and element number. The vertices are projected onto a view plane. A view plane is simply an invisible plane surface stationed between the eyepoint and the objects being looked at. It is perpendicular on the line-of-sight vector and orientated so that the v and w axes lie on the view plane.

After projection onto the viewing plane, the description of the object is no longer three dimensional. Instead, it might be thought of as a series of coordinate points (w, v) which after being connected by straight lines yield a perspective drawing giving the illusion of a three dimensional scene. It should be emphasized that every object and surface pattern must be projected in this manner for each frame displayed. There are 30 frames displayed per second. The frame after projection is no longer represented as coordinate pairs (w, v) but rather as screen coordinates (i, j). There are 1000 scan lines 'i' and 1000 scan elements 'J'. Each coordinate pair w, v becomes an i, j pair. Objects so far in the distance that they occupy less than one scan element are beyond the resolution of the display and are eliminated.

Priority Determination

Since every object is convex (inside angle between each adjacent face of a three-dimensional object is less than 180 degrees), once back surfaces are removed for a given viewpoint position, no hidden line problem will exist within that object.

A model is composed of one or more objects. All faces within an object have the same priority. Thus, in a model, the selection of a scan element gray level based on the closer object is a matter of determining which object within a model is closer to the viewpoint. In such a case, the modeler has specified one or more planes designated separation planes. It is usually a vertical face in one of the objects making up the model. The difference between the perpendicular distance from the origin to this plane 'd_A' and the dot product between the viewpoint vector ('R_p') and a unit normal ('n_A') to the separation plane is positive if the viewpoint is on the near side of the plane. Thus, a determination is made of the relative priority each object has within a model.

A similar scheme is followed for priority determination between models. This is based on the model "footprints." A footprint is the projection of a model's perimeter onto the ground. As with an object, this footprint must be convex.

Edge Control Words

A list is generated of all edges for the current frame. Since a

projected edge (either visible or invisible) is simply a line on the viewing screen, it can be completely described by:

1. The (i,j) coordinate pair defining the start of the edge.
2. An edge slope, expressed in scan elements/scan line.
3. The scan line (i) on which the edge stops.
4. Priority number of object which contains the edge.
5. Miscellaneous face color and object identification information.

Edge Generator

Using these data, the edge generator transfers edge control words for a particular scan line to an interface memory. The edge control word for a particular scan line might simply be one of the edge control words previously defined or it could be generated by adding the slope value to the previous 'J' value to compute the crossing for that line. If this scan line lies just below the bottom of an edge, the control word would be eliminated from the list of edge control words for the scan line. The location of an image edge for a particular scan line is simply a J value. No further processing is done until all edge control words for a particular scan line are formed in the interface memory.

Edge Ordering

The output from the edge generators, of which there are two, is a list of data words for a particular scan line. This list of edge-crossing data words is unordered with respect to increasing scan element number J. For any given scan element number J, there may exist zero, one, or more edge data words specifying an edge crossing at that element. The edge ordering algorithm generates a compact list of ordered edge data words, by increasing J value, such that at a given value of J, all edge control words with a common element crossing number are listed consecutively.

Priority Processor

Priority processing is done on an element by element basis. As each element is examined, a table with 143 slots is updated to reflect all potentially visible surfaces pierced by a view ray through that element. Table entries are ordered by priority. When all crossings at that element are processed into the table, it is scanned starting at the high priority end. The first surface encountered is the visible one. Its position in the table equals its

priority, which is used to access the gray shade value to be assigned to the current scan element. The priority processing takes place in parallel for all channels. Fourteen tables are being updated and checked, and 14 gray shade decisions are being made at once. The gray shade value of each scan element encompasses the effects of sun angle and curved surface shading. These effects were added from data in the edge control words and originally specified as options during data base creation.

Modification of the intrinsic gray shade assigned to a surface is based on the distance to the object from the viewpoint. The determination of the proper modification function to be applied depends on whether the surface is part of a 3-D object, a 2-D object, or a light. Fading is applied to introduce the effects of limited visibility conditions, such as fog or ceilings, as well as normal horizon haze. As the electron beam in the CRT scans across a raster line, the computed and modified digital gray shades are passed through a digital-to-analog converter and sent over coaxial cables to the platform along with video sync signals. The image on each 36-inch CRT, the largest cathode ray tubes ever built, is generated one scan line at a time. However, the electron beam actually scans the odd-numbered lines (beginning at the top) until it reaches the next to the last line on the display. At that point, it returns to complete the frame by scanning the even lines. The interlacing of scan line output eliminates flicker completely, since 60 "fields" are procured per second. In this way, a complete image is built up from individual scan lines. The total frame exists for 1/30 second before an updated image is ready for display. Motion is achieved in exactly the same way that movement results from a succession of individual movie frames.

IV. CONSTRAINTS

Face

Faces must be convex and all vertices must be in the same plane. The maximum number of vertices in a face is 16. If curved surface shading is to be used four vertices are the maximum with three preferable.

Object

Objects may be 2-D or 3-D. The maximum number of edges in an object is 32, except that with disjoint faces the maximum is 16. The maximum number of faces in an object is 16.

Model

The maximum number of objects in a model is 30 for a 2-D model, 15 for a 3-D model and 100 for a moving model. The moving model has a maximum of 200 objects for all three levels of detail. For a model to be used as a hood to move with the viewpoint, the maximum number of objects is 16. Each model may have three levels of detail. A maximum of 400 small models may be in any 36-by-1250-nautical-mile-stripe. A maximum of 200 small models may be in any 36-by-36-nautical-mile-square. A maximum of 400 large models may be in any 200-by-1250-nautical-stripe. A maximum of 200 large models may be in any 200-by-200-nautical-mile-square. The objects in a model may touch but must not overlap and must form a listable set. The footprints of models should not overlap; however, the footprint calculated by the computer is not always the smallest possible size.

Environment

In one environment there may be a maximum of 2000 models, 40,000 objects and 300,000 edges.

Viewpoint

The real-time display has a maximum of 200 models and 512 objects that can be displayed in 1/30 second. The maximum that can be displayed in all 14 screens in both cockpits is 2560 edges, 200 models, 256 objects and 30 special purpose lights. A maximum of 256 edges may cross one raster line.

REFERENCES

1. Monroe, E. G. Environment data base development process for the ASUPT CIG system. AFHRL-TR-75-24, AD-A017845. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, August 1975.

APPENDIX A

DECK ORDERING

OBJECT CARD DECKS - To run type "ACTIVATE O"

The deck consists of:

1. One or more objects with:
    a. An object header card
    b. A bounding plane card if needed
    c. Vertex cards
    d. Face cards
2. End of file card
3. Object delete cards
4. End of file card

MODEL CARD DECKS - To run type "ACTIVATE M"

The deck consists of:

1. One or more models with
    a. A model header card
    b. One model locate card and model multiply card if needed for each object in the model
    c. Normals cards if needed
2. End of file card
3. Partition cards if needed
4. End of file card
5. Model delete cards if needed
6. End of file card

ENVIRONMENT CARD DECKS - To run type "ACTIVATE E"

1. Any mixture of environment & environment delete cards
2. End of file card

AIRPORT ELEVATION CARD DECKS - To run activate AIRPORT

1. Airport Cards in sequence by algebraic value of x, then y within x.
2. End of file card.

APPENDIX B

CARD FORMATS

OBJECT HEADER CARD

Column(s)	Title	Enter
1	Object Type	LT for 3-D LIGHT O for 3-D OBJECT S for 2-D SURFACE OR LIGHT
3-6	Object Name	4 alphanumeric characters
7-8	Number of Vertices	1-32
9-10	Number of Faces	1-16
11	Curved Surface Shading	1 If desired (Faces should be triangles)
12	Fading	1 if 3-D
14	Disjoint	1 if disjoint faces are used
15	Light	1 if object is light
16	Dimming	1 if light is to be dimmed.
17-18	Dimming Range	1-8. Determines distance at which light goes to 2 by 2 size as follows. The object changes to 2 by 2 pixels when an object of the diameter indicated would become too small to see: 1 for 0' 2 for 5' 3 for 10' 4 for 25' 5 for 50' 6 for 100' 7 for 250' 8 for 15000'
19-20	Extinguishing Range	1-8 Determine distance at which light disappears.
21	Directional Light	1 if object is a direction light.

(Requires Bounding Planes).

22	Blinking Lights	1 if object is a blinking light.
27-31	ON	Number of frame times blinking light is to be ON
40-44	OFF	Number of frame times blinking light is to be OFF
53-57	DELAY	Number of frame times delay before light starts blinking (0 for Random Start)

BOUNDING PLANES CARD FOR DIRECTIONAL LIGHTS

Column(s)	Title	Enter
1	Bounding Plane	B
3-6	Object Name	4 alphanumeric characters
29-32	Horizontal Width	Horizontal field of view (1-180 degrees)
41-45	Azimuth	0-360 degrees heading at which cone of view is to be aimed. (0 is north, 90 is east).
55-58	Vertical Width	Vertical field of vision (1-90 degrees)
68-71	Elevation Angle	0-90 degree angle at which cone of view is to be elevated from the horizon.

VERTEX CARD

Column	Title	Enter
1	Vertex	V
3-6	Data Set No.	4 alpha-numeric characters
7-8	Vertex Number	1-32
23-34	X	x coordinate
35	miles	1 if x coordinate in nautical miles. Blank if feet.
36-47	Y	y coordinate
48	miles	1 if y-coordinate in miles
49-60	Z	z coordinate
61	miles	1 if z coordinate in miles

FACE CARD

Column(s)	Title	Enter
1	Face	F
3-6	Object Name	4 alphanumeric characters
8-9	Face Number	1-16
11-12	Gray Shade	0-63 (use 37-63 for light: GRAY SHADES 0-36 are darkened for dusk & night)
14-15	Number of Vertices	1-32
17-18	Vertices	Vertices of face in their clock-wise viewing order.
19-20		
79-80		

Model Header Card

Column	Title	Enter
1-2	Header	MH
3-6	Model Name	4 alphanumeric characters
7	Level of Detail	1-3
8	Variable Runway Light	1 if model is a runway light (Brightness is determined by Runway Light Switch on Console)
18	Model type	0 if a surface model 1 - if a 3-D model 2 - if part of moving model 3 - if a 1 model moving model
19-20	Layer	0-15 - 0 is on top 15 is on bottom
21-27	Critical Dimension	1-70,000 to override calculated

Model Locate/Rotate Card

Column	Title	Enter
1-2	Locate Model	ML
3-6	Model Name	4 alphanumeric characters
7	Level of Detail	1-3
28-31	Object Name	4 alphanumeric characters
32-42	X	x coordinate location of object within the model
43	Miles	1 if x coordinate is in miles
44-54	Y	y coordinate location of object within the model
55	Miles	1 if y coord is in miles
56-66	Z	z coordinate location of object within the model

67	Miles	1 if z coord is in miles
68-71	X-axis	counterclockwise rotation about the x-axis in degrees
72-75	Y-axis	counterclockwise rotation about the y-axis
76-79	Z-axis	counterclockwise rotation about the z axis

Model Multiply Card

Column	Title	Enter
1-2	Multiply	NM
3-6	Model Name	4 alphanumeric characters
7	Level of Detail	1-3
29-31	Object Name	4 alphanumeric characters
32-42	X coord	factor by which this dimension is scaled.
44-54	Y coord	
56-66	Z coord	

NORMALS CARDS

Normal cards are required only for Partitioned Moving Models with curved surface shading to smooth the junctions between partitions.

Normal Cards follow the model cards for each partition of the moving model.

The Normal Cards must in order by columns 10-13, the same as the major sequence.

Then columns 8-9 must be in same sequence as the minor sequence.

All the normals specified will be averaged for the final result used by curved surface shading.

Column	Title	Enter
1-2	Model Normal	MN
3-6	Model Name for Partition	4 alphanumeric characters
7	Level of Detail	1-3
8-9	Vertex No.	Vertex number of 1st object (There may be more than one entry for one vertex.)
10-13	1st Object Name	Alphanumeric 1st object name
14-17	2nd Object Name	Alphanumeric 2nd object name (May be same as 1st object)
18-19	Face Numbers from 2nd object	Face numbers relating to 2nd object name to be used in vertex normal calculation.
21-22	Face Numbers	

24-26 thru 48-49	Face Numbers	

PARTITION PLANE CARDS

11 Partition Card

A complex moving model is in actuality composed of a number of models called partitions. In order to establish on-line priority among the partitions, it is necessary to define or partition planes which isolate these partitions from one another, and specifically to pick a set of planes (more than one plane may separate two partitions) which satisfies the conditions of the off-line listability algorithm. In order for the listability algorithm to be satisfied, one of the following conditions must be met.

1. Of the three combinations of pairs in any triplet of partitions, the same separation plane must be used to separate these partitions in at least two of the pairs.
2. There exists only one mandatory separation plane for each and every pair.

A moving model made up of partitions must have partition planes defined after the sequentially alphanumerically defined model cards. An end of file (EOF) card usually follows the model cards. After the EOF card, Partition Plane Cards in sets of three for each defined plane follow for priority ordering.

Column	Title	Enter
1-2	Partition Plane Vertex 3	11
3-14	X	x coordinate decimal point col. 11
15-26	Y	y coordinate decimal point col. 23
27-38	Z	z coordinate decimal point column 35
39-40	True Partition Numbers	1-99 Enter all True Partitions for this partition plane.
41-42		
43-44 thru 79-80		

12 Partition Card

Column	Title	Enter
1-2	Partition Plane Vertex 2	12
3-14	X	x coordinate decimal point col. 11
15-26	Y	y coordinate decimal point col. 12
27-38	Z	z coordinate decimal point col. 35
39-40	False Partition Numbers	1-99. Enter all false partitions for this partition plane.
41-42		
43-48		
thru		
79-80		

13 Partition Card

Column	Title	Enter
1-2	Partition plane Vertex 3	13
3-14	X	x coordinate
15-26	Y	y coordinate
27-38	Z	z coordinate

ENVIRONMENT CARD

Column	Title	Enter
1	Environment	C
2-5	Model Name	4 alphanumeric characters
6	Level of Detail	1-3
7	Miles	1, if x, y, and z coordinates are in miles
10-21	X	x coordinate location of model in environment
22-33	Y	y coordinate location of model in environment
34-45	Z	z coordinate location of model in environment
46-52	Rotate Counterclockwise about Z-Axis	Degrees rotation of model about z-axis.
53	Strobe	1, if model & strobe light
54	Day	1, if model to appear in day scene

55	Dusk	1, if model to appear in dusk scene
56	Night	1, if model to appear in night scene
57	10%	1, if model to appear in 10% scene
58	25%	1, if model to appear in 25% scene
59	50%	1, if model to appear in 50% scene
60	75%	1, if model to appear in 75% scene
61	90%	1, if model to appear in 90% scene
62	100%	1, if model to appear in 100% scene
63	Variable Runway light	For Run Light override
64-65	Priority Layer	1-15 for layer override
66-67	Priority Bits	00, 01, 10, or 11 for Priority Bits
68-72	Critical Dimension	1-70,000 for override
73	X miles flag	1, if miles
74	Y miles flag	1, if miles
75	Z miles flag	1, if miles
76-79	Environment Name	4-character environment name, if different from model name.
80	Environment L.O.D.	Level of Detail if different from model Level of Detail

OBJECT DELETE CARD

Column	Title	Enter
1	Delete Object	D
3-6	Object Name	4 alphanumeric characters

MODEL DELETE CARDS

Column	Title	Enter
1	Delete Model	D
3-6	Model Name	4 alphanumeric characters
7	Level of Detail	1-3

ENVIRONMENT DELETE CARD

Column	Title	Enter
1	Delete ENV model	D
2-5	Environment Model Name	4 alphanumeric characters

END OF FILE CARD

Column	Enter
1	Multi-punch 2, 3, 4, 5

AIRPORT ELEVATION CARDS

To allow for changes in surface elevation, airport data cards are provided as a means of entering elevation data for selected areas of the environment.

Column	Title	Enter
1	ft/mi.	0, if coordinates in feet 1, if coordinates in miles
2-11	X coord	x coordinate
12-31	Y coord	y coordinate
22-31	Z coord	z coordinate

Airport Data Card. This card is used to input elevation data for up to 15 airports in the environment, so that the surface plane elevation may be adjusted on-line by interpolating between adjacent elevation data points. Twelve points are entered for each airport, the four corners of the airport plus eight additional points away from the airport on the extension of the airport boundaries. The airport cards must be in sequence by x, then y within x.

APPENDIX C

FILE FORMATS

OBJECT LIBRARY FORMAT

The Object Library is maintained in Standard FORTRAN formated 588-word records as follows:

DATA NAME	NO. CHARS	FORMAT	DESCRIPTION
IRC	2	I2	RECORD CODE
DSN	4	A4	DATA SET NAME (OBJECT ID)
INV	2	I2	NUMBER VERTICES THIS OBJECT
INF	2	I2	NUMBER FACES THIS OBJECT
ISH	1	I1	SHADED OBJECT? 1 = yes 0 = no
IFAD	1	I1	FADED OBJECT? 1 = yes, 0 = no
ISUNI	1	I1	SUN ILLUMINATION? 1 = yes, 0 = no
IDIM	1	I1	DIMMING? 1 = yes, 0 = no
ILITE	1	I1	IS THIS OBJECT A LIGHT? 1 = yes, 0 = no
IBLK	1	I1	IS IT A BLINKING LIGHT? 1 = yes, 0 = no
IDIR	1	I1	IS IT A DIRECTIONAL LIGHT? 1=yes, 0=no
IDR	2	I2	DIMMING RANGE
IER	2	I2	EXTINGUISHING RANGE
IDIS	1	I1	IT IS A DISJOINT SURFACE? 1 = yes, 0=no
CYCON	9	F9	NUMBER CYCLES ON IF BLINKING LIGHT
SPACES	4	4X	UNUSED
CYCOF	9	F9	NUMBER CYCLES OFF IF BLINKING LIGHT
SPACES	4	4X	UNUSED
DELAY	9	F9	NUMBER CYCLES DELAY BEFORE FIRST "ON" CYCLE
SPACES	4	4X	UNUSED
VERTARRAY	1152	96F12.3	3 x 3 ARRAY OF VERTEX COORDINATES
IFCEARAY	1024	512I2	32 x 16 ARRAY OF VERTEX NOS IN EACH FACE
IGRYARAY	32	16I2	16 WORD ARRAY OF FACE GRAY SHADES
IFNARAY	32	1612	16 WORD ARRAY OF NO. OF VERTICES IN EACH FACE

HORIZ	12	F12.3	HORIZONTAL FIELD OF VIEW (DIRECTIONAL LIGHTS)
AZMTH	12	F12.3	AZIMUTH FIELD OF VIEW (DIRECTIONAL LIGHTS)
VERIS	12	F12.3	VERTICAL VISIBILITY (DIRECTIONAL LIGHTS)
ELANGL	12	F12.3	ELEVATION ANGLE (DIRECTIONAL LIGHTS)

MODEL LIBRARY FORMAT

The Model Library is maintained in standard FORTRAN unformatted, variable length records. For each model there exists a model header record, which is followed by as many object records as there are objects in that model. The layouts of these records follow:

Model Header Record

DATA NAME	TYPE	DESCRIPTION
BUF (1)	WORD	NO. words in rest of header record
BUF (2)	WORD	Model/object flag; 0 = model, 1 = object
CMOD	WORD	Model name
MOVMOD	WORD	Moving Model Flag; 0 = moving mod, 1 = fixed
KRONMT	WORD	Number of objects in this model
LITWDS	WORD	Number of words of special light data
MODIND	WORD	Model type indicator; 0 = 2-D, 1 = 3-D
KLOP	WORD	Level of Detail
NSP	WORD	Number of separation planes this model
KPRILAY	WORD	Priority layer (Surface models only)
LITIND	WORD	Special Light Indicator
CRITDIM	REAL	Critical dimension of this model.
GCX	REAL	Geocenter x coordinate
GCY	REAL	Geocenter y coordinate
GCZ	REAL	Geocenter z coordinate
IENVT	WORD	Environment type
TNS	WORD	No. words of footprint coordinates
FP	12 REALS	6 Sets of foot print x and y coordinates - moving model has x, y, & z for 18 words
ZMAX	REAL	Maximum z value in this model
KOUT	WORD	No. pairs separated by this plane

XN	REAL	x-component of the normal to the plane
ZN	REAL	z-component of the normal to the plane
DIST	REAL	Perpendicular distance from plane to origin
FOPAIR	BYTE ARRAY	Object pairs for this plane, 2 bytes per pair
LCT	REAL ARRAY	15 words of light codes
SLITDAT	REAL ARRAY	Special light data words

Object Record

DATA NAME	TYPE	DESCRIPTION
IOBJWDS	WORD	No. words in rest of object record
IOBJFLG	WORD	Object record flag = 1
COBJ	WORD	Object name
IFACECW	WORD	Face control word code
IFACEDR	WORD	Face dimming range code
IFACEER	WORD	Face extinguishing range code
GCX	REAL	Object geocenter x coordinate
GCY	REAL	Object geocenter y coordinate
GCZ	REAL	Object geocenter z coordinate
RADS	REAL	Object geocenter radius
NVO	Word	Number of vertex data words
VERT	REAL ARRAY	Vertex coordinates
NVNO	WORD	No. Vertex normal data words
VERTN	REAL ARRAY	Vertex normal coordinates
NFO	WORD	Number of faces in this object
FACEN	REAL ARRAY	Face normal coordinates gray shade
NEDGES	WORD	Number of edge pointer data words
IEDGE	BYTE ARRAY	Edge point data words

ENVIRONMENT LIBRARY FORMAT

1.	Word	Model Name
2.	Word	Number of count words is the total of the words in items 2-5.
3.	Word	Number of words of Priority data (6-10)
4.	Word	Numer of words of special light data (11-12)
5.	Array	One word for each object. Each word contains the number of words in one object (13-22).
6.	Word	Bit 0 is set if object is 3D. Bits 1-7 contains number of objects minus 1. Bits 8-14 contains number of separation plane minus 1.

		Bits 15-18 contain the priority layer. Bit 31 is set if there are any special lights.
7.	Array	Footprint of model. Always has 6 vertices. x and y coordinate only in 12 words for fixed model. Has x, y, and z coordinates in 18 words for moving model. The values are scaled B24.
8.	Word	In Fixed Models ONLY. The coordinate of the highest point in the model.
9.	Array	Reserved for on-line to insert the active object numbers, 9 Bits per object. Bits 5-13, 14-22, and 23-31 are used. The number of words reserved is one word for each 3 objects.
10.	Array	For each separation plane: Word 1, Bits 0-12 contain the number of object pairs for this separation plane MINUS 1. Word 2, Contains y component of Normal scaled B0 (y really comes before x) Word 3, Contains x component of Normal. Word 4, Contains z component of Normal Word 5, Contains distance from plane to original. Words 6 to end contain pairs of objects, 8 bits per object. The number of words is one word for each two pairs of objects.
11.	Word	Special light flags. 15 objects are represented by pairs of bits in Bits 2-31. The even Bit is set if the object is a blinking light. The odd bit is set if the object is a directional light. There are words in the follow data only for the bits that are set.
12.	Array	Special light data. For each object with any bit set in the flag word (Item 11), one word of blinking light data and/or 15 words of directional light data will follow. The blinking light word will have three fields. Bits 2-11 Frame times ON Bits 12-21 Frame times OFF Bits 22-31 Frame times delay to delay before starting. (If delay is zero, start time will be random.) The 15 words of directional light data consist of 4 sets of normals and the geocenter of the light scaled B24.

Object Format in a Model in an Environment

262 Words Maximum in Object

13.	Word	Object	Name Not valid in old environments.
14.	Word	Sizes	Word Counts Bits 0-2 always have 3 as number of Geocenter words names 1. Bits 2-7 have number of edge words minus 1. Bits 8-15 have number of face words minus 1. Bits 16-23 have number of vertex normal words minus 1. Bits 24-31 have number of vertex words minus 1.
15.	Array	Vertices	3 words each. Maximum of 96 words. x, y, and z scaled B24.
16.	Array	Vertex Normals	2 words each. Maximum of 64 words. Bit 0-15 of first word contain x component of normal scaled B0. Bits 16-31 of first word contain y component. Bit 0-15 of second word contain z component.
17.	Array	Face Normals.	4 words each. Maximum of 64 words. First 3 words contain x, y, & z face normal components. Fourth word in face control word. Bit 8 is variable runway light Bit 9 is Surface Flag, 1 is 2D Bit 10 is Light Bit 11 is Point Light (Not implemented) Bit 12 is Dimming Bit 13 is Fading Bit 14 is Sun Illumination Bit 15 is Curved Surface Shading Bit 16-19 is Dimming Range Code Bit 20-23 is Extinguishing Range Code Bit 24-31 is Gray Shade 0-255=Card 0-63
18.	Array	Edges.	1 word each. Maximum of 32 words. Bits 1-5 First Vertex Number Bits 6-10 Second Vertex Number Bit 21 Disjoint Face Flag Bit 22 Ignore included Face Flag Bits 23-26 Included face number. Included means it is visible when first

			vertex to second vertex is in clockwise order.
			Bit 27 Ignore excluded Face Flag
			Bit 28-31 Excluded Face number
			Excluded means it is visible when first vertex to second vertex is in counterclockwise order.
19.	Word	Geocenter	X coordinate of object geocenter B24
20.	Word		y coordinate of object geocenter B24
21.	Word		z coordinate of object geocenter B24
22.	Word	Critical Dimension	Diameter of OBJECT. Scaled B27.

FIXED DISC FORMAT

The heart of the visual system is the fixed head disc. Some of the files present on the fixed-head disc have counterparts on the moving disc system or on magnetic tape but it is easier to understand the files in terms of the fixed-head disc formats. The fixed-head disc has a capacity of 8,388,608 bytes which is divided into 512 tracks. Each track is divided into 32 sectors of 512 bytes or 128 words. The files on the fixed disc are as follows:

TRACK	SIZE	NAME	DESCRIPTION	
0	7	syn	bps-batch processing operating system.	
7	3	lid	program directory	syslbr
10	80	lbr	program library	syslbr
90	50	ut1	FORTRAN file 4	
140	30	ut2	FORTRAN file 2	
170	30	ut3	FORTRAN file 3	
200	80	ut4	FORTRAN file 1	
280	120	ut7	FORTRAN file 7	
400	624		environment	
1230			last track on disc	

The environment is treated as though it were continuously addressable as a string of words running from 0 to 2,555,904. Words are 4 bytes long. The format for the environment is as follows:

track	sector	relative word	description
400	0	0	Wndef, cpldsk window definition
400	1	128	Wndmx1, lbi1
400	2	256	Wndmx2, lbi2
400	3	384	Chil
400	4	512	Gray shade for day
400	5	640	Gray shade for night

400	6	768	Gray shade for dusk
400	8	1,024	Etab airport data elevation table 5 sectors
400	13	1,664	Xtab stripe pointers 2 sectors
400	15	1,920	Moving model directory 14 words
400	16	2,048	Tmt model directory 4 words each
406	0	10,240	Xcross cross index to models 4 words each
496	0	393,116	Scratch area where models are built
512	0	458,752	Models
700	0	1,228,800	End of small environment
768	0	1,507,328	Diagnostic data start M file
828	0	1,753,088	Matrix multiply input data P file
912	0	2,097,151	Highest address available to on-line
1023	0		End of diagnostic data last track of disc
1024	0	2,555,904	First address past the end of the disc

APPENDIX D

PROGRAMS

PROGRAM	AIRPORT-ELEVATION DEFINITION

DESCRIPTION

This program reads the airport data cards. If the data are input in miles, this program converts it to feet, sorts the data y within x), and converts the data to binary point 24. The airport data are replaced in the environment.

CALLING PROGRAM	Binary Point (BINPT) Fixed Head Disc
Simulator (FHDSIM)	
INPUTS	Airport Cards (Card Reader) Error Messages (Line Printer)

PROGRAM	BINPT-BINARY POINT CONVERSION

DESCRIPTION

This subroutine converts FORTRAN floating point numbers to binary, fixed point numbers.

CALLING SEQUENCES	CALL BINPT (I, Floating, Fixed) where I determines the scaling of the result which is placed in "FIXED". I = 1 for B0 I = 2 for B24 I = 3 for B22 I = 4 for B31 I = 5 for B23 I = 8 for B1
CALLING PROGRAMS	Environment (EDTNMT) Airport (AIRPORT) Matrix Multiply (MTRXMULT)
CALLED PROGRAMS	None
INPUTS	Parameters from Calling Program
OUTPUTS	Parameters to Calling Program Messages (Line Printer)

PROGRAM BLDMODLS-BUILD MODELS

DESCRIPTION

This program reads the data output by the Separation Planes Program and Rotate-Locate-Multiply Program and builds two files: A file of models to be added to the model library (DISC FILE 4), and a file of the moving model partials (DISC FILE 3).

CALLING PROGRAM	SEPLAN
CALLED PROGRAMS	None
INPUTS	Separation Planes data (DISC FILE 2) Model components calculation data (DISC FILE 1)
OUTPUTS	New Model data (DISC FILE 4) Moving model partials (DISC FILE 3)

PROGRAM CALNORM-NORMAL CALCULATION

DESCRIPTION

This program computes the normals to the separation planes that have been input to the program that joins the moving model partials.

CALLING PROGRAM	JOIN
CALLED PROGRAMS	None
INPUTS	Separation Planes Data (Common memory)
OUTPUTS	Separation Planes Normals (Common Memory)

PROGRAM EDTNMT-Environment Update

DESCRIPTION

This program adds, replaces, and deletes models in an existing Environment. The models to be added are obtained from the model library. Environment cards are used to control the process. The same model may be used more than once in the environment. The model name or the level of detail may be changed with the environment card.

SUBROUTINES	FHDSIM, LROT, LROTS, BINPT

INPUTS	Environment cards, model library
OUTPUTS	Updated environment library.

PROGRAM	FHDSIM FIXED-HEAD DISC SIMULATOR

DESCRIPTION

This program allows the off-line software to read or write the fixed head disc, independently of the B.P.S. software. It also allows programmers to use a second fixed-head disc.

CALLING PROGRAMS	Environment Program (EDTNMT) Airport Program (AIRPORT) Read TTY Program (RDTTY) Modify Model (MOD) List Environment data (LISTENV)
CALLED PROGRAMS	None
INPUTS	Parameters from Calling Program
OUTPUTS	Data on Disc (if a write) Data from Disc in user's buffer (if a read) Error Messages (TTY)

PROGRAM	JOIN-MOVING MODEL PARTIALS

DESCRIPTION

This program reads the moving model partials from disc file 3 and combines them into a single model on disc file 1 for input to the Model Library File Maintenance Program. This program is executed when a moving model in excess of 16 objects is processed. This program also requires input cards which define the separation planes for the model in the form of three vertices per plane, along with the relative object numbers and whether they are on the true side or the false side of the planes.

CALLING PROGRAM	BLDMODLS
CALLED PROGRAMS	CALNORM XTR
INPUTS	Separation planes cards (Card Reader) Moving Model Partials (Disc File 3)

OUTPUTS	Single Moving Model (Disc File 1) Error Messages (TTY)

<u>PROGRAM</u> LISTBY-LISTABILITY VERIFICATION

DESCRIPTION

For each possible viewpoint within the environment, the priority of objects within a model must be such that their order can be listed with no contradictions or inconsistencies. The set of separation planes generated are tested to insure that this ordered list is possible, independent of viewpoint. The listability algorithm tests every possible subset of three objects within a model to insure the three can be formed into an ordered list. If every subset of three is is listable, then the entire set can be listed. If any subset of three cannot be ordered, the modification of selected separation planes is done, insuring no other set of three is disturbed.

CALLING PROGRAM	MODELCAL
CALLED PROGRAMS	MINENT 1, NRCALC, OBPAIR
INPUTS	Set of planes eligible for listing (MEMORY)
OUTPUTS	Error Messages (TTY)

<u>PROGRAM</u> LROT LOCATE-ROTATE PROGRAM

DESCRIPTION

This subroutine makes the yaw angular adjustments to the positional and orientation data coming from the model system. Adjusts yaw of x and y for one vertex, and if the first parameter is not equal to 5, x and y are relocated.

CALLING PROGRAM	Environment Program (EDTNMT)
CALLED PROGRAMS	None
INPUTS	Parameters from Calling Program
OUTPUTS	Parameters to Calling Program Printout of LOCATE/ROTATE coordinates

PROGRAM LROTS-LOCATE/ROTATE for SEPARATION PLANES

DESCRIPTION

This subroutine makes the yaw angular adjustments to the positional and orientation data coming from the model system. Additionally, this subroutine computes the new perpendicular distance based on the angular adjustments for separation plane data.

CALLING PROGRAM	Environment Program (EDTNMT)
CALLED PROGRAMS	None
INPUTS	Parameters from Calling Program
OUTPUTS	Parameter to Calling Program Printout of Separation Plane Normals

PROGRAM MINENT 1-MINUS ENTRY SELECTION

DESCRIPTION

This subroutine finds the entry in the table for a given row, which is the current separation plane number being tested for listability.

CALLING PROGRAM	Listability Verification (LISTBY)
CALLED PROGRAMS	None
INPUTS	Parameters, Table of Plane Numbers
OUTPUTS	Error Messages (TTY)

PROGRAM MODELCAL-MODEL CALCULATIONS

DESCRIPTION

MODELCAL sequentially processes each model's disc input data and writes each model's output data on disc until all modes have been processed. Model header data for a model is read into core followed by one object's data. Each object is initially processed through object transformation (scale, rotate and locate) extremes, geocenter channel assignment radius if directional lights, boundary planes and finally face normal calculations. All object data are stored by relative object number. Object special light data are stored with

the model header data. Next, each object's vertex normals are calculated for curved surface shading. Finally each object's edge pointer table is derived and stored in the output core by relative object number. After all objects for a model have been processed the model header record and related object records are written on disc.

CALLING PROGRAM	MODELCRDS
CALLED PROGRAM	LISTABILITY VERIFICATION (LISTBY)
INPUTS	Disc file 7 contains model header and object data. Disc file 4 contains curved surface shading exception data.
OUTPUTS	Model header records each followed by related object data on disc file 3 for separation plane calculations. All remaining model header and related object data on disc file 1. Error Message - Line printer.

<u>PROGRAM</u> MODLCRDS-MODEL CARD EDIT & EXTRACT PROGRAM

DESCRIPTION

This program reads and edits model cards and extracts from the object library master file all objects required by each model writing the data out to disc. The input cards consist of groups of model header cards, each followed by its respective component cards. Card codes have been changed, MH to 20 ML to 25, MM to 26, and NM to 27. This program writes out to Disc File 7 the model header information followed by the object data pertinent to each model. The vertex normal cards are written out to Disc File 4.

CALLING PROGRAM	MODEL PROGRAM
CALLED PROGRAMS	MODEL CARD CODE CONVERSION PROGRAM
INPUTS	Model Cards Object Library
OUTPUTS	Model Header records each followed by object data for That model (Disc File 7) Vertex normal cards (Disc File 4) Error Messages (Line Printer)

<u>PROGRAM</u> MODLIBFM-MODEL LIBRARY FILE MAINTENANCE

DESCRIPTION

This program performs file maintenance on the model library file. The delete cards (if any) are read in through the card reader, sorted internally, and stored in memory. The model library master tape file is read into memory and written out to Disc File 7 for temporary storage. Any model for which a delete card was encountered is not copied into Disc File 7. New models being added to the file have been stored on Disc File 4 by the Build Models Program. Incoming moving model partials, if any, are on Disc File 3. If a single moving model is being created, it will have been stored on disc file 1 by the program called JOIN. All three files will be merged onto magnetic tape, thereby creating an updated model library master tape file. A list of all models deleted during each run is printed on the line printer. The user has the option to get a list of all model identifications and the number of objects in each.

CALLING PROGRAM	Model Executive Program
CALLED PROGRAMS	None
INPUTS	Old Model Library File New Model Data (Disc File 4) New Moving Model Data (Disc File 1) New Moving Model Partials (Disc File 3) Delete Cards (Card Reader).

PROGRAM : OBJLIBFM-OBJECT LIBRARY FILE MAINTENANCE

DESCRIPTION

This program performs file maintenance on the Object Library File. The delete cards (if any) are read in through the card reader, sorted internally and stored in memory. The object library master tape file is read into memory, one data set at a time and written out to temporary storage on Disc File 7. Any data set for which a delete card was stored is not copied onto Disc File 7. New data sets being added to the file have been stored on Disc File 4 by the Coplanar-Convexity Program. Disc Files 4 and 7 are merged and written out together and written out to magnetic tape, thereby creating an updated object library master file.

CALLING PROGRAM:	Object Execution
CALLED PROGRAMS	None

INPUTS	Old Object Library File New Object Data (Disc File 4) Delete cards (Card Reader)
OUTPUTS	New Object Library File

<u>PROGRAM</u> PREPROC-OBJECT DATA VALIDATION PRE-PROCESSOR

DESCRIPTION

This program reads the object data cards and converts the user-oriented card codes to a format acceptable to the other programs in the object subsystem. The converted data are stored on Disc File 1. Error messages regarding invalid card codes are printed on the line printer.

CALLING PROGRAM	Object Program
CALLED PROGRAMS	None
INPUTS	Object Data Cards (Card Reader)
OUTPUTS	Converted object data (Disc File 1) Error Messages (Line Printer)

<u>PROGRAM</u> PROG7351-OBJECT DATA VALIDATION PROGRAM

DESCRIPTION

This is simply an edit program. This program reads, validates, and stores the object data sets. When an error is detected, an appropriate message will be printed.

CALLING PROGRAM	Object Program
CALLED PROGRAMS	None
INPUTS	Converted Object Data (Disc File 1)
OUTPUTS	Edited Object Data (Disc File 7) Error messages (Line Printer)

<u>PROGRAM</u> PROG7352-OBJECT CALCULATIONS

DESCRIPTION

PROG7352 calculates the face normals of the object data sets and determines whether the faces are convex and the vertices describing them are coplanar and whether the faces form a convex object. If these conditions are not met, appropriate error messages will be printed. The error-free data sets will be stored to await further processing.

CALLING PROGRAM	OBJECT PROGRAM
CALLED PROGRAMS	None
INPUTS	New Object Data (Disc File 7)
OUTPUTS	Error-free New Object Data on Disc File 4 Error Messages - Line Printer

<u>PROGRAM</u> SEPLAN SEPARATION PLANES

DESCRIPTION

This program determines a set of planes which separate objects within a model and performs a check on the listability of this set so that object priority can be uniquely established. Then this routine computes the geocenter of the model, forms a six-vertex footprint of the model, and computes the model critical dimension unless the user has elected to input this dimension.

CALLING PROGRAM	Modelcal
CALLED PROGRAMS	COPLAN DOT EXTR MINENT NRCALC OBPAIR READOF VINDEX
INPUTS	Model headers and related object data required for separation plane calculation (DISC FILE 3)
OUTPUTS	Separation Planes Data (DISC FILE 2) Error messages (TTY)

<u>PROGRAM</u> XTR-EXTREME CALCULATION

DESCRIPTION

This program finds the extremes for the maximum and minimum x, y, and z coordinates for an entire moving model.

CALLING PROGRAM	JOIN
CALLED PROGRAMS	None
INPUTS	EXTREMES OF MOVING MODEL PARTIALS (PARAMETERS)
OUTPUTS	EXTREMES OF ENTIRE MOVING MODEL (PARAMETERS)

APPENDIX E

OPERATING INSTRUCTIONS

OBJECT SYSTEM

1. Load Object Library or Clear It.
2. Put Object Cards in Reader
3. Activate O
4. Wait for Computer to Type EOJ Objects
5. Save Object library

MODEL LIBRARY

1. Load Model Library or Clear It.
2. Put Model Cards in Reader
3. Activate M
4. Wait for Computer to Type EOJ Models
5. Save Model Library

ENVIRONMENT SYSTEM

1. Load Environment Library.
2. Put Environment Cards in Reader
3. Activate E
4. Wait for Computer to Type EOJ ENV
5. Save Environment Library

AIRPORT ELEVATION.

1. Load Environment Library
2. Put Airport Cards in Reader
3. Activate AIRPORT
4. Save Environment Library

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